

# CHARACTERISTICS AND CARBON STABLE ISOTOPES OF FLUIDS IN THE SOUTHERN KERALA GRANULITES AND THEIR BEARING ON THE SOURCE OF CO<sub>2</sub>

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Carbon dioxide-rich inclusions commonly occur in the banded charnockites and khondalites of southern Kerala as well as in the incipient charnockites formed by desiccation of gneisses along oriented zones. Comprehensive microthermometric measurements constrain their densities to be in the range of 0.95-1.0 g/cm<sup>3</sup> in banded charnockites, 0.87-0.97 g/cm<sup>3</sup> in khondalites and 0.83-0.95 g/cm<sup>3</sup> in incipient charnockites. The combined high density fluid inclusion isochores and the range of thermometric estimates from mineral assemblages (Fig. 1) indicate entrapment pressures in the range of 5.4 to 6.1 Kbar. The CO<sub>2</sub> equation of state barometry closely compares with the 5 ± 1 Kbar estimate from mineral phases for the region (1,2,3). The isochores for the high density fluid inclusions in all the three rock types pass through the P-T domain recorded by phase equilibria, implying that carbon dioxide was the dominating ambient fluid species during peak metamorphic conditions.

In order to constrain the source of fluids and to evaluate the mechanism of desiccation, we have taken up detailed investigations of the carbon stable isotope composition of entrapped fluids. We report here the results of our preliminary studies in some of the classic localities in southern Kerala namely,

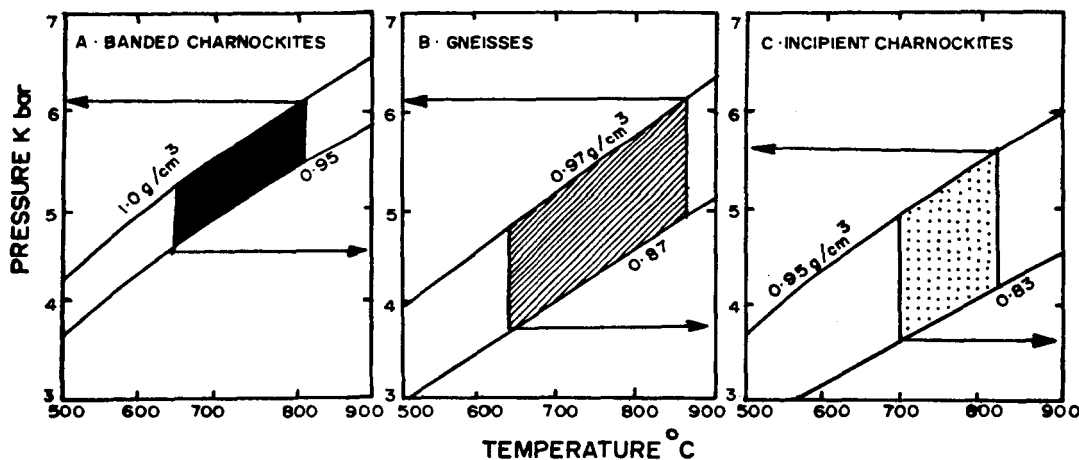


Fig.1 Combined P-T data from mineral thermometers and fluid inclusion isochores for the Kerala granulites. The shaded regions represent the P-T domains, with arrows denoting the highest and lowest pressure estimates.

Ponmudi, Kottavattom, Manali and Kadakamon. In Ponmudi and Kottavattom, garnet-biotite gneisses transform into patchy charnockites and the arrested prograde reaction is manifestly that of biotite+garnet+quartz to orthopyroxene +K-feldspar+ilmenite (4). In the Manali quarry, east of Trivandrum, interbanded and co-folded banded charnockites and garnet-biotite+cordierite gneisses are cut by later incipient charnockites developed along oriented zones. Two of our samples come from Kadakamon area where calc-silicates are interlayered with cordierite-bearing banded charnockites.

A stepped heating technique was adopted whereby quartz samples from the granulites were heated in 100°C steps from 300 to 1200 degrees and the abundance and isotopic composition of the carbon dioxide evolved at each step was measured on an ultrasensitive mass spectrometer. The stepped release profiles of all the samples are broadly similar (eg. shown in Fig. 2) and show a maximum carbon release between 600 and 800°. This release is interpreted as carbon dioxide from decrepitation of fluid inclusions and is characterised by the isotopically heaviest carbon in the samples. This has been systematically checked by visual decrepitation of fluid inclusions in doubly polished plates of the same samples, by heating the inclusions in a Leitz-1350 heating stage, when the carbonic inclusions recorded maximum explosions between 500 and 800°C.

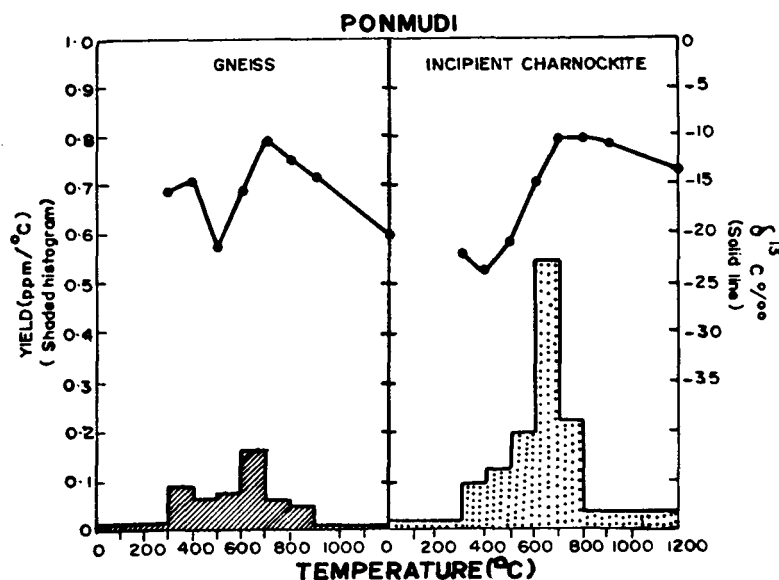


Fig. 2 Stepped-release profiles for gneiss-incipient charnockite pairs. The histograms represent carbon dioxide abundance and the thick lines join the stable carbon isotopic composition at each step.

The analytical results show that the banded charnockites and gneisses contain about 50-60ppm carbon, whereas the incipient charnockites are characterised by more abundant (100-200ppm) carbon. The carbon isotopic compositions range from -10‰ to -12‰ in banded charnockites and -8‰ to -10.3‰ in the gneisses. The incipient charnockites show  $\delta^{13}\text{C}$  values between -7.5 and -10.3‰. The calc-silicate yielded a  $\delta^{13}\text{C}$  value of +1.2‰. Carbon dioxide generated by decarbonation reactions would be enriched in lighter carbon isotopes as compared to the carbonate. The contrasting values of +1.2‰ for the Kadakamon calcsilicate and -10‰ for the interlayered banded charnockite preclude an origin by decarbonation. The -7.5‰  $\delta^{13}\text{C}$  value for the incipient charnockite of Manali shows marked enrichment in heavier carbon as compared to the associated banded charnockites (-12.3‰) and gneisses (-11‰), suggesting a juvenile source. The isotope values for the main release peak, when plotted against carbon abundance show no pronounced correlation between gneiss-incipient charnockite pairs, suggesting that simple fluid flushing did not occur. Moreover, at Ponmudi and Kottavattom, the  $\delta^{13}\text{C}$  values of incipient charnockites are isotopically lighter and with essentially no pronounced difference from the  $\delta^{13}\text{C}$  values of the precursor gneisses. Isotopic exchange between an externally derived fluid and graphite in the rock would considerably enrich the carbon dioxide with lighter carbon. We hence interpret the lighter  $\delta^{13}\text{C}$  values in these samples to be the result of the interaction of externally derived fluids with graphite that is ubiquitously present in the precursor gneisses and incipient charnockites in these localities.

Eventhough the apparent small shift in carbon isotope composition during charnockite formation is consistent with internal buffering, the observed carbon dioxide abundance in the incipient charnockites as compared to their precursor gneisses argues for external buffering of  $\text{CO}_2$ . This leads us to infer that eventhough some fluid flushing did occur, it equilibrated with graphite present in the rocks during charnockite formation.

## REFERENCES

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